Engineering High-Stability Beamline Instrumentation for Advanced X-ray Microscopy at Sirius

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The novel experimental capabilities enabled by 4th-generation light sources impose stringent requirements on beamline instrumentation to support X-ray microscopy with increasingly high spatial and temporal resolution. At Sirius, these demands have driven the development of experimental systems combining high mechanical stability, advanced optics, controlled sample environments, and integrated experiment control.

This talk presents an overview of the engineering approaches adopted at Sirius, focusing on enabling technologies embedded in high-performance systems developed in-house, including high-dynamics double-crystal monochromators (HD-DCMs), exactly-constrained Kirkpatrick–Baez (ECKB) nanofocusing systems, and nanoprobe stations such as Tarumã, Mogno, and Sapoti, as well as ongoing developments for the Orion BSL-4 imaging facility, including Hibisco, Timbó, and Sibipiruna.

Key technologies include deterministic optomechanical design based on exact constraint principles, stiffness-driven architectures targeting nrad/nm -level stability, and integrated strategies for vibration mitigation, thermal management, and metrology-assisted assembly. These practices directly enhance imaging performance by minimizing wavefront distortions, reducing focal spot instabilities, and ensuring reproducible alignment, enabling improved spatial resolution and measurement reliability.

These capabilities are complemented by advanced sample environments for in-situ and in-operando experiments, and by distributed control and data acquisition systems enabling precise synchronization and high-throughput operation. In parallel, Systems Engineering practices have been introduced to strengthen traceability between scientific objectives and engineering implementation.

This overview highlights how coordinated engineering efforts have supported advanced X-ray microscopy at Sirius over the past decade, and outlines future challenges associated with increasing system complexity.